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Maintenance Resource Prediction in the Facility Life-Cycle Process

by
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FOREWORD

This research was conducted for the Directorate of Military Programs, Headquarters, U.S. Army Corps of Engineers (HQUSACE), under various Research, Development, Test, and Evaluation (RDTE) and reimbursable funding sources. Work began under RDTE in 1980-1983 and continued as reimbursable projects during 1984-1988. The technical monitor for the RDTE part was Dr. Larry Schindler, CEMP-EC, and for the reimbursable parts was Ms. Val Corbridge, DAEN-ZCP-B.

The work was performed by the Facility Systems Division (FS), U.S. Army Construction Engineering Research Laboratory (USACERL). The Principal Investigators were Dr. Edgar Neely and Mr. Robert Neathammer. Assistance was provided by Mr. James Stirn. Dr. Michael J. O'Connor is Chief of FS.

COL Everett R. Thomas is Commander and Director of USACERL, and Dr. L.R. Shaffer is Technical Director.

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MAINTENANCE RESOURCE PREDICTION IN THE FACILITY LIFE-CYCLE PROCESS

1 INTRODUCTION

Background

In the Military Construction, Army (MCA) process, a one-page DD Form 1391 is submitted about 5 years before a facility is needed. At this time, an economic analysis (EA) is performed to compare alternative ways of meeting the requirement. Later, as the complete DD Form 1391 is prepared, the EA is updated--a process that continues until the facility is funded. The EA compares total life-cycle cost of the MCA alternative with others such as renovation of existing facilities or leasing. These analyses ensure that the most cost-effective option is chosen, and are mandated for MCA.[1]

Life-cycle cost analyses require three categories of costs: initial, operating, and maintenance. Initial costs are usually projected through existing cost estimating programs such as the Computer-Assisted Cost Estimating System (CACES) and standard publications such as Means and Dodge. Operating costs can be estimated by using energy consumption models such as the Building Loads Analysis and System Thermodynamics (BLAST) program or the Trane Company's Trace program. However, there is no accurate method of estimating maintenance costs.

The main difficulty in projecting maintenance costs is that no comprehensive data base of maintenance resources for facilities exists--either within the Army or the private sector. Some historical data is available from the Building Owners' and Managers' Association reports and other sources. However, the little information available is subject to the uncertainties of what standards of maintenance were used to maintain the facilities for which the data was collected. Within the Army, the Integrated Facilities System (IFS) contains some historical information, but does not have the ability to retain costs by types of components in a building. Moreover, IFS users have not always entered all data and kept it current. Reliance on this type of information usually results in an inaccurate EA.

Related to the lack of maintenance data is the problem of estimating future maintenance and repair (M&R) costs for existing facilities. One way these costs have been predicted is to use the previous years' expenditures multiplied by factors to account for inflation and deterioration due to work not accomplished (backlog of maintenance and repair--BMAR). The fallacy in this method is that what was spent in the past was the funding received, *not* the funding required to maintain the facilities properly.

Recognizing these deficiencies, the U.S. Army Corps of Engineers (USACE) asked the U.S. Army Construction Engineering Research Laboratory (USACERL) to develop a maintenance and repair (M&R) cost data base. This data base would be used by USACE designers in performing life-cycle cost analyses for the design of new facilities. Further, to ensure that enough M&R funds are programmed for future needs, USACERL was asked to develop prediction models for outyear maintenance requirements of the Army facility inventory. These tools were originally expected to support the installations as they assume the planning function from higher chains of command.

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[1] Military Handbook (MIL-HDBK) 1190, *Facility Planning and Design Guide* (Department of Defense, September 1, 1987); Army Regulation (AR) 11-18, *The Cost and Economic Analysis Program* (Headquarters, Department of the Army, 7 May 1990); AR 415-15, *Military Construction Army (MCA) Program Development* (Headquarters, Department of the Army, December 1, 1983).

Objective

The twofold objective of this research was to develop (1) a comprehensive data base containing M&R cost data for Army Facilities and (2) prediction models for outyear maintenance requirements.

Approach

A steering committee composed of representatives from all Army offices involved in maintenance resource programming and planning guided, reviewed, and approved all work on the project. The study objectives were achieved as follows:

1. Future maintenance planning and programming functions were determined by working directly with the Department of the Army (DA) offices that establish the related policies.

2. The current set of definitions was reviewed by the steering committee and Headquarters, Department of the Army (HQDA). Several meetings were conducted with USACERL to try and reach a consensus on one set of standard definitions. (A standard set of definitions between Family Housing and the facilities engineers has not yet been achieved.)

3. Efforts were made to identify work by other organizations in this area (e.g., literature survey and field trips to Federal agencies).

4. Using the above information, several prediction models were developed and presented to the steering committee for review. The models selected by the committee are described in Chapter 4.

5. A series of prototype data bases was developed, reviewed, field-tested, and verified as described in Chapter 3.

6. To automate the data bases, the computer systems described in Chapter 5 were field-tested at the Headquarters, Major Command (MACOM), and installation levels.

7. A logical plan to implement the systems was initiated and is still under development between Headquarters, USACE, the U.S. Army Engineering and Housing Support Center (USAEHSC), and USACERL.

Appendix A describes the study concept and plan in detail.

Scope

This report describes the research and development (R&D) for the maintenance cost data base and the outyear prediction models. The data base contents, computer system descriptions, and user manuals are published as separate USACERL reports (see Chapter 2 for a list).

Mode of Technology Transfer

Present worth tables summarizing the M&R data bases for use by facility designers will be issued as a supplement to Technical Manual 5-802-1, *Economic Studies for Military Construction--Applications*. The automated prediction models for use in programming outyear requirements will be provided to HQDA, MACOMs, and installations through USAEHSC as an optional Army computer system.

2 RESEARCH PROGRESS AND REPORTS PUBLISHED

Research Progress

The research was conducted over 7 years. Most of the tasks were performed in parallel with reviews by an Army-wide steering committee at major milestone points. Yearly presentations on the research progress were made at the annual Worldwide Real Property Management System (RPMS) conferences.

HQDA formed an Army-wide maintenance steering committee (users' group) to guide the research. This committee was composed of one voting representative from every Army office involved in planning and programming of maintenance resources. The four largest MACOMs were asked to participate in the steering committee; three of these became actively involved in the research. Ten installations also served on the steering committee: six in the United States--Forts Devens, Bragg, Wood, Sill, Harrison, and Ord, and four in Germany--Baumholder, Wuerzburg, Pirmasens, and Grafenwohr. The Army Reserve and National Guard also had voting members on the committee. The steering committee was open to all DOD elements. Official liaison members from the Air Force and Navy also participated in the steering committee meetings.

A standard briefing procedure was established. The HQDA staff was briefed the day before the steering committee meeting. The Assistant Chief of Engineers (ACE) was briefed after steering committee meetings when major decisions were made.

The first task was to determine one set of standard definitions for use by all Army elements. A list of all current definitions was compiled and reviewed by both the research team and the steering committee member organizations independently. Many current definitions overlapped, and several required knowledge of the organization that performed the work before they could be applied.

The second task was to determine the state of the art in planning and programming maintenance in the Army, the private sector, and other Government agencies. Major Federal agencies were contacted and visited. Most agencies were not performing maintenance resource plans and program functions beyond the budget year. City and state governments were contacted as well as colleges and universities. Stanford University was the only organization found that had a long-range planning program. Several large companies and management organizations also were contacted, but none had any long-range maintenance planning programs.

The review of the current programming and planning activities within the Army showed that the installations had relatively little functional work in this area. All functional work was performed by the MACOMs and HQDA. An initiative to move the planning and programming function down to the installation level was underway within HQDA. It was expected to take at least 3 years for full implementation at the installations. The purpose of performing planning and programming at the installation level is to obtain a more accurate picture of Army needs based on the actual facilities maintained. The installations need tools to help them perform these activities. Therefore, part of this research effort was to identify the tools needed, develop computer programs to support the function, and test the prototype programs at several installations.

The first meeting of the entire steering committee was held after tasks 1 and 2 were completed. The steering committee charter and research proposal were reviewed and accepted. The results of the state-of-the-art survey were presented to the committee. The current and proposed definitions were presented and discussed. All participants could agree on using Webster's definition of maintenance, but beyond this point, there was very little agreement. Most participants could see that the terms were overlapping and in some cases cyclic in nature. However, it was agreed not to pursue standard definitions further.

The third task was to visit the 10 test installations to discuss how planning and programming functions could be performed at the installation levels. Since the installations were not currently involved in these activities, the discussions proved very interesting. All installation personnel stated that the installation was underfunded to do the work that should be performed and that the budget figures have very little to do with actual facility maintenance needs. Most installations seemed reluctant to consider performing this new function, citing personnel shortages and a lack of knowledge about their facilities as the two major problems. The installations were willing to work with the researchers to develop and test new functions on a limited basis.

The fourth task was to discuss the future of maintenance planning and programming functions with the HQDA staff. There was a general consensus that the functional area was not receiving adequate attention from the Army and that the functions should be extended to the installations in the near future. The timeframe for extending the function to the installations was unknown.

The fifth task was to develop a set of alternative maintenance resource prediction models and to discuss the pros and cons of each model. The results of this effort are given in Appendix B.

The steering committee met again to review current planning and programming functions and six alternative models. The committee voted to use the historical funding model as an interim solution until a model based on facility components could be produced. The fixed percentage of current replacement cost model was also to be pursued. A fast program based on the results of the component model was needed at HQDA.

The sixth task was to develop several data bases that could be applied within the prediction models. The development of each data base is described in Chapter 3.

The seventh task was to develop several sets of maintenance resource prediction models. The models would span the range of possible data input from the simplest, with very little input, to the most complex with a large amount of detail. One purpose of the large number of model sets was to explore the effect of the input data complexity on the accuracy of the results. The complete set of models developed are described in Chapter 4. The computer systems are discussed in Chapter 5.

A third steering committee meeting was held at this point to select the facility category codes to be modeled for the first test of the prototype Maintenance Resource Prediction Model (MRPM). The decision was made to address buildings initially as buildings account for over 60 percent of the maintenance expenditures annually. Family housing and unaccompanied personnel housing were selected since the two combined categories account for 26 percent of yearly maintenance expenditures. These two current use categories were to be modeled completely by USACERL and the results reviewed by the steering committee.

The eighth task was to test the models at all organizational levels within the Army and to revise the data base and process based on the results. Tests were performed using four different complementary methods. The first test consisted of sampling family housing and barracks at each of the 10 test sites. USACERL collected and entered all facility component and cost data for the models, ran the models, and presented the results to each installation.

The steering committee met again to review the results of the family housing and unaccompanied personnel housing test results. The steering committee believed that it could not make a final decision based on such a small and limited test scope. The general consensus was to continue the research by sampling other current use building facility category codes at the six U.S. test installations. The steering committee voted to provide each test installation with a personal computer (PC) to perform a hands-on test. This was the second level of testing.

A meeting of MPRM users (Forts Bragg, Leonard Wood, Devens, and Ord) was held to discuss progress and determine if the installations could make a decision about implementing the system. It was agreed that the MRPM should be implemented fully, covering all facilities at installations, before a recommendation could be made on fielding the model. Funding was received to fully implement the MRPM at Forts Bragg, Leonard Wood, Devens, and Ord.

The third test was to completely model four installations in the United States (Forts Bragg, Leonard Wood, Ord, and Devens) and Wuerzburg in Germany. Test results were to be used in planning the expansion and future implementation of the system. Concurrent with this test, a fourth series of tests was performed by other organizations involved in the planning and programming functions. The MRPM research was used by two Government contractors performing work on historic family houses. The research was also used by contractors involved in the long-range stationing study (LRSS) and a total Army Real Property Planning system (RPLANS).

The ninth task in this project was to perform an 80-year or 120-year analysis on each of the facilities modeled. The purpose of this analysis was to develop a summary prediction model based solely on the facility's age, floor area, and current use. This research is described in Chapter 3.

The tenth and final step in the basic research program was for the steering committee to evaluate all tests and make a recommendation on the direction the Army should move in planning and programming functions and support. The results of this step are described in Chapter 6.

Products and Reports Published

This is one of several reports addressing maintenance resource prediction in the facility life-cycle process. This report presents the scope of the total research effort. Figure 1 shows the relationships between the products and reports developed during this research project.

The first research product is a data base containing the labor, material and equipment resources required to perform maintenance tasks related to every building construction component (Figure 1, Task Resource Data Base). This data base includes labor hour, Washington, DC material costs, and equipment hour resource information. The frequency of task occurrence is also given. This information is published as a series of four Special Reports by engineering system: (1) architectural, (2) heating, ventilating, and air-conditioning (HVAC), (3) plumbing, and (4) electrical.[2] The title for the series is "Maintenance Task Data Base for Buildings." Figure 2 shows an example from this data base. This data is also available in electronic form. The data base is used within the MRPM Individual Facility Component System which operates on a PC with the IBM Disk Operating System (DOS). This program allows a facility to be defined by entering the components and component quantities that comprise the facility. The tasks are used to determine the resources required annually to keep the facility maintained. Engineered Performance Standards (EPS) were used to generate task data. A typical EPS task is shown in Table 1.

[2]E.S. Neely et al., *Maintenance Task Data Base for Buildings: Architectural Systems*, Special Report P-91/23 (U.S. Army Construction Engineering Research Laboratory [USACERL], May 1991); E.S. Neely et al., *Maintenance Task Data Base for Buildings: Heating, Ventilation, and Air-Conditioning Systems*, Special Report P-91/21 (USACERL, May 1991); E.S. Neely et al., *Maintenance Task Data Base for Buildings: Plumbing Systems*, Special Report P-91/18 (USACERL, May 1991); E.S. Neely et al., *Maintenance Task Data Base for Buildings: Electrical Systems*, Special Report P-91/25 (USACERL, May 1991).

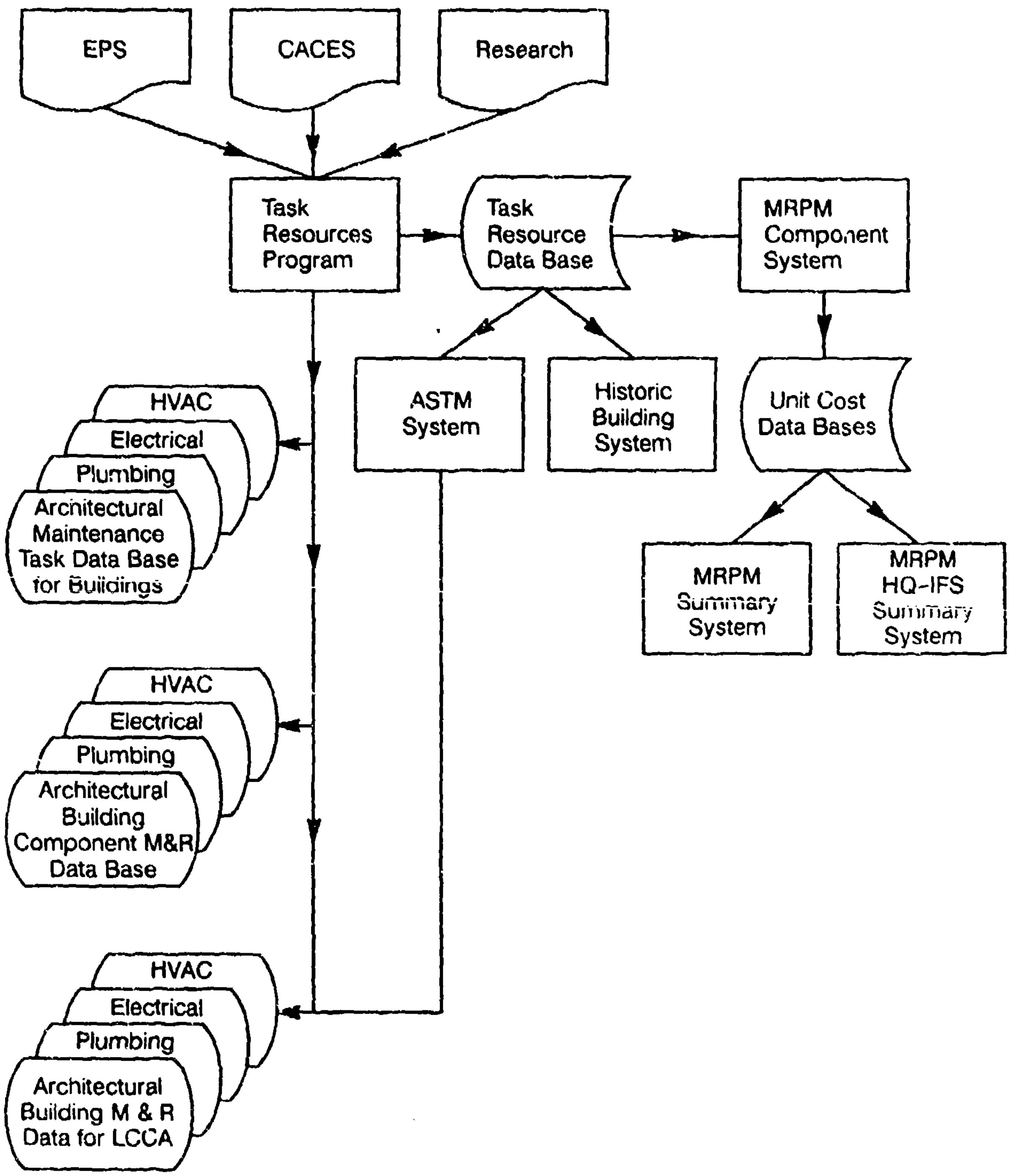

Figure 1. Maintenance reports for buildings.

TASK DATA FORM

Task Code: 0311356

Component: SHINGLES System: ROOFING Subsystem: ROOF COVERING

Task Description: REPLACE NEW OVER EXISTING - SHINGLED ROOF

Unit of Measure: SQUARE FEET Frequency of Occurrence H: 18.00 A: 20.00 L: 22.00

Persons per Team: 2 Task Duration: 0.0150 hours Once every (H,A,L) years

Trade: ROOFER Task Classification: 1

Labor Resources

Subtask Description	
1. SET UP/SECURE/TAKE DOWN LADDER	0.000160
2. REPLACE WITH NEW SHINGLE	0.012887
3. CLEAN UP	0.010000

Material Resources

Description	Quantity	Unit Cost
SHINGLE	1.0 SF	0.2600
MASTIC	1.0 SF	0.1500
		0.4100

SUMMARY

Resources UOM	Direct	Ir[illegible]t	Total
Labor Hours	0.023047	0.006914	0.029961
Material Cost $	0.410000		0.410000
Equipment Hours			0.014981

Figure 2. Typical task data form.

Table 1

Typical EPS Task Format*

No.	Work Unit Description	Hours
1	Remove and Install Screw	0.32040
2	Remove and Install Panel	0.29280
3	Lube Bearings, Fan, Motor, Pump	0.07260
4	Adjust Belt Tension	0.10200
5	Adjust Float	0.04000
6	Sensory Inspect Bearings	0.25260
7	Fill Out Inspector Report	0.01375
	Total	1.09415

*Task: recurring maintenance--evaporative condenser or metal cooling tower (25-ton and over air-conditioning system).

The second research product is a component resource summary using the task data developed in the first product. The component resource summary covers the first 25 years of a facility's life. The tasks for the component were scheduled and combined into one set of annual resource requirements. This annual resource information is published as a series of four Special Reports[3] titled "Building Component Maintenance and Repair Data Base." An example from this data base is shown in Table 2. The data base is also available in electronic form. This data can be used to perform special economic analyses such as one for a 20-year life using a 10 percent discount rate.

The third research product is a set of 25-year present worth factor tables. The component data developed in the second product was used to form a set of 25-year present worth factor tables for use by designers in component selection for discount rates of 7 and 10 percent. The annual component resource values were multiplied by the appropriate present worth factor and added for the 25 years to produce one

[3] E.S. Neely et al., *Building Component Maintenance and Repair Data Base: Architectural Systems*, Special Report P-91/27 USACERL, May 1991; E.S. Neely et al., *Building Component Maintenance and Repair Data Base: Heating, Ventilation, and Air-Conditioning Systems*, Special Report P-91/22 (USACERL, May 1991); E.S. Neely et al., *Building Component Maintenance and Repair Data Base for Buildings: Plumbing Systems*, Special Report P-91/30 (USACERL, May 1991); E.S. Neely et al., *Building Component Maintenance and Repair Data Base: Electrical Systems*, Special Report P-91/19 (USACERL, May 1991).

Table 2

Typical Component Summary

25 YEAR COMPONENT LISTING

Cases No.: 031134 - Roll Roofing **031135 - Shingles**

LABOR HOURS	MATERIAL $	EQUIPMENT HOURS	YR	LABOR HOURS	MATERIAL $	EQUIPMENT HOURS
0.0076	0.0165	0.0039	1	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	2	0.0024	0.0220	0.0013
0.0090	0.0165	0.0046	3	0.0026	0.0220	0.0014
0.0076	0.0165	0.0039	4	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	5	0.0032	0.0330	0.0017
0.0090	0.0165	0.0046	6	0.0026	0.0220	0.0014
0.0076	0.0165	0.0039	7	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	8	0.0024	0.0220	0.0013
0.0090	0.0165	0.0046	9	0.0026	0.0220	0.0014
0.0414	0.7496	0.0207	10	0.0032	0.0330	0.0017
0.0076	0.0165	0.0039	11	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	12	0.0026	0.0220	0.0014
0.0090	0.0165	0.0046	13	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	14	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	15	0.0034	0.0330	0.0018
0.0090	0.0165	0.0046	16	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	17	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	18	0.0026	0.0220	0.0014
0.0090	0.0165	0.0046	19	0.0024	0.0220	0.0013
0.0414	0.7496	0.0207	20	0.0332	0.4675	0.0167
0.0076	0.0165	0.0039	21	0.0026	0.0220	0.0014
0.0076	0.0165	0.0039	22	0.0024	0.0220	0.0013
0.0090	0.0165	0.0046	23	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	24	0.0026	0.0220	0.0014
0.0076	0.0165	0.0039	25	0.0032	0.0330	0.0017

set of resource values. This information is published as a series of four reports[4] titled "Building Maintenance and Repair Data for Life-Cycle Cost Analyses." Table 3 shows an example from this data base. The data base is also available in electronic form.

The first three resource columns provide data to allow the designer to calculate the life-cycle costs at any location by multiplying by the correct labor rate, equipment rate, and material geographic location factor. This multiplication and addition have been performed for the Military District of Washington, DC, and are given in the fourth column of the table. The right section of the table is information that can be entered into computer systems that perform life-cycle cost analysis.

The fourth research product is a task resource maintenance computer program. This program is written in DBASE III. This program maintains the task data base and produces task, component, and life-cycle cost tables. User's and programmer's manuals are published as USACERL ADP Reports.

The fifth research product is the MRPM Individual Facility computer system. This system operates on a DOS PC system that allows facilities to be modeled by entering their components. Resource predictions are produced by applying the individual tasks and then forming resource summaries by subsystems, systems, facilities, installations, reporting installations, MACOM, and Army. User's and programmer's manuals are published as USACERL ADP Reports[5].

The sixth research product is the MRPM Facility Summary computer system. Two summary systems have been implemented. One summary system is a module of HQ-IFS. The second is a DOS PC based system. Both are macro-level computer systems developed for installations, HQDA, and the MACOMs. The macro-level system uses the most basic data contained in the current facility real property inventory files: (1) current facility use, (2) floor area, and (3) construction date. User's and programmer's manuals for the systems are published as a USACERL ADP Reports.[6]

The seventh research product is an analysis of the resources to maintain buildings by current use. This is summary data of the individual facility information obtained by use of the component model at several installations. The results of this research are published in two USACERL Special Reports[7].

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[4] R.D. Neathammer et al., *Building Maintenance and Repair Data for Life-Cycle Cost Analyses: Architectural Systems*, Special Report P-91/17 (USACERL, May 1991); E.S. Neely et al., *Building Maintenance and Repair Data for Life-Cycle Cost Analyses: Heating, Ventilation, and Air-Conditioning Systems*, Special Report P-91/20 (USACERL, May 1991); E.S. Neely et al., *Building Maintenance and Repair Data for Life-Cycle Cost Analyses: Plumbing Systems*, Special Report P-91/24 (USACERL, May 1991); E.S. Neely et al., *Building Maintenance and Repair Data for Life-Cycle Cost Analyses: Electrical Systems*, Special Report P-91/26 (USACERL, May 1991).

[5] E.S. Neely et al., *Maintenance Resource Prediction Model (MRPM) Individual Facility System User's Manual*, ADP Report P-91/12 (USACERL, January 1991); E.S. Neely et al., *Maintenance Resource Prediction Model (MRPM) Individual Facility System Programmer's Manual*, Special Report P-91/28 (USACERL, March 1991).

[6] E.S. Neely et al., *Maintenance Resource Prediction Model Summary System (MRPMSS) User's Manual*, ADP Report P-91/03 (USACERL, October 1990); E.S. Neely et al., *Maintenance Resource Prediction Model Summary System (MRPMSS) Programmer's Manual*, Draft USACERL Report; E.S. Neely et al., *HQ-IFS Maintenance Resource Prediction Model (MRPM) User's Manual*, ADP Report P-91/04 (USACERL, October 1990); E.S. Neely et al., *HQ-IFS Maintenance Resource Prediction Model (MRPM) System Manual*, ADP Report P-91/02 (USACERL, October 1990).

[7] E.S. Neely et al., *Maintenance Resources by Building Use for U.S. Army Installations*, Special Report P-91/29 (USACERL May 1991).

Table 3

Life-Cycle Cost Analysis

EPS BASED MAINTENANCE AND REPAIR COST DATA FOR USE IN LIFE CYCLE COST ANALYSIS ($ PER UNIT MEASURE)													PAGE 1
COMPONENT DESCRIPTION		PRESENT WORTH OF ALL 25 YEAR MAINT. AND REPAIR COSTS (d=10%)				ANNUAL MAINTENANCE AND REPAIR PLUS HIGH COST REPAIR AND REPLACEMENT COSTS							
		By Resources			Wash. D.C. Total	Annual Maintenance and Repair			Replacement and High Cost Tasks				
	UM	Labor	Mat'rl	Equip.		Labor	Mat'rl	Equip.	Yr	Labor	Mat'rl	Equip.	
ARCHITECTURE													
ROOFING													
ROOF COVERING													
BUILTUP ROOFING	SF	0.03990	0.37220	0.02000	1.25	0.00488	0.03172	0.00244	28	0.04938	0.70490	0.02469	
PLACE NEW MEMBRANE OVER EXISTING -BUILTUP									14	0.02414	0.69960	0.01207	
MOD. BIT./THERMOPLASTIC	SF	0.02440	0.33090	0.01180	0.87	0.00248	0.03219	0.00119	20	0.05659	0.85860	0.02829	
MEMBRANE REPLACEMENT OR REPAIR - M.B./T. R									20	0.05659	0.85860	0.02829	
THERMOSETTING	SF	0.01680	0.23950	0.00850	0.61	0.00174	0.02203	0.00088	20	0.03683	0.69960	0.01841	
MEMBRANE REPLACEMENT - THERMOSETTING ROOF									20	0.03683	0.69960	0.01841	
SLATE	SF	0.01850	0.10440	0.00890	0.51	0.00259	0.01459	0.00124	70	0.06885	6.04200	0.03442	
CEMENT ASBESTOS	SF	0.01820	0.24340	0.00870	0.64	0.00254	0.03404	0.00122	70	0.05437	0.75190	0.02718	
TILE	SF	0.01550	0.20990	0.00740	0.55	0.00217	0.02935	0.00103	70	0.10169	3.07400	0.05084	
ROLL ROOFING	SF	0.07140	0.42700	0.03640	2.00	0.00754	0.01557	0.00387	10	0.04141	0.74963	0.02070	
TOTAL ROOF REPLACEMENT - ROLL ROOF									10	0.04141	0.74963	0.02070	
SHINGLES	SF	0.02210	0.22150	0.01170	0.71	0.00259	0.02385	0.00140	40	0.04118	0.74497	0.02059	
REPLACE NEW OVER EXISTING - SHINGLED ROOF									20	0.02996	0.43460	0.01498	
METAL	SF	0.01460	0.11060	0.00740	0.43	0.00205	0.01547	0.00103	30	0.36265	2.17300	0.18132	
FIBERGLASS RIGID STP. ROOF	SF	0.02190	1.15340	0.01080	1.64	0.00232	0.06269	0.00113	20	0.04543	6.01550	0.02272	
CONCRETE, SEALED PANEL ROOF	SF	0.04300	0.11750	0.02120	1.07	0.00601	0.01643	0.00297	60	0.06123	24.07419	0.03061	
CONCRETE, SEALED PANEL RF4	SF	0.03900	0.08410	0.02020	0.95	0.00545	0.01176	0.00282	300	0.04342	24.07419	0.02171	
CONCRETE SEALED POURED	SF	0.09830	0.63020	0.04950	2.80	0.01375	0.08811	0.00692	500	3.81056	18.03219	1.90528	
FIBERGLASS, RIGID ROOF	SF	0.03800	1.15340	0.01930	1.99	0.00463	0.06269	0.00236	20	0.04133	6.01550	0.02066	
TOTAL ROOF REPLACEMENT - FIBERGLASS RIGID									20	0.04133	6.01550	0.02066	
See NOTES on the last page of this table for Explanation of Column Headings													

3 DATA BASE DEVELOPMENT

Average of Actual Expenditures

HQDA requires each installation to submit a Technical Data Report annually. This report summarizes cost expenditure data into approximately 70 functional use category codes in the Army Management System (AMS). It also contains the number of facilities within the installation. For buildings, the measurement unit is the gross square feet of floor area.

Data for each year is reviewed for obvious errors and corrected. A cost per unit measure is calculated by summing the yearly costs (adjusted for inflation) for each of the past 5 years and dividing the total cost by the total units of measure. This process results in an average cost per unit measure known as the Recurring Maintenance Factor (RMF).

During the past 8 years, the Army has funded some installations much more money than usual to reduce their backlog of maintenance projects. There was no attempt to adjust the RMFs to account for this higher than average funding.

RMFs were calculated for each installation, MACOM, and the total Army. The total Army RMFs are the only figures published in Army Regulation (AR) 420-16, *Facilities Engineering Reports.*

Component Tasks

To obtain accurate maintenance costs for a component, a list of tasks to be performed during the component's life must be obtained. The labor equipment and material resources and frequency for each task must be estimated. Research in this area revealed that such a comprehensive data base did not exist. A committee composed of HQDA, installation, and USACE District offices reviewed the current situation and recommended the development of this data base using the Department of Defense (DOD) EPS manuals as a starting point.

Over 60 percent of maintenance expenditures are in building facilities. Therefore, the steering committee decided to begin with building facilities.

The first task was to divide the building into smaller parts such as systems, subsystems, and components. The Federal Construction Council and several other national professional societies had previously adopted a uniform format UNIFORMAT for such divisions. This format was used for this research to ensure consistency throughout the facility life.

A list of components used in Army construction was developed. This list was reviewed for completeness and adopted as the first draft.

For each component, a list of all tasks that had to be performed during the component's life was developed. This task list was reviewed for completeness and adopted as the first draft. A standard definition of "task" was accepted: a task is defined as the work performed on a component by a single trade. A standard format for printing task resources was adopted and is shown in Figure 2. A comprehensive description of the task development process and the complete task data base have been published in the USACERL Special Report series "Maintenance Task Data Base for Buildings."

The next step involved the most work. Labor hours, equipment hours, crew size, material quantity and costs and performance frequencies had to be determined.

Labor Hours

As noted earlier, DOD had previously adopted the EPS for determining labor hours to perform maintenance tasks. These standards were originally developed by the U.S. Navy and are published as Army Technical Bulletins (TB) in the 420 series. EPS are based on either methods-time-measurement studies or work sampling studies. Using these techniques, times for performing work elements were estimated and combined to provide task times. An example from TB 420-8, *Heating, Cooling, and Ventilating Handbook*, for a task and its work elements is shown in Table 1 (Chapter 2).

The total time of 1.09415 hr represents the direct or actual time required to do the work once the worker is onsite. An additional four factors must be considered in estimating the total time for the job: (1) travel time (to go to the job site and return), (2) craft allowance (personal time, planning, balancing, unavoidable delay), (3) job preparation (shop and job site), and (4) material handling allowance.

Travel times are directly related to a facility's location and are not included in the task data base. (The actual travel time factor must be included to obtain a complete resource profile for a specific facility.) The last three factors are normally specified as a percentage of the work day or work time. The three were combined into one figure for each application. For steamfitters, this figure is 40 percent. For all other trades, it is 30 percent.

Equipment Hours

"Equipment" refers to the normal maintenance truck used by the maintenance crew. For most tasks, the crew size is one person. For large replacement (and roofing) tasks, there may be two or more people on the crew. The number of equipment hours is obtained by dividing the labor hours by the number of people in the crew.

Material Costs

To minimize the initial input data, it was decided to record the unit costs as the basis--not each individual material type with its appropriate quantity. This means that the material costs are for a specific year at a specific location. Since Federal agencies have adopted the Washington, DC area as the base location for costs, it was used for this data base. The costs in this data base are for the Washington, DC area in July 1985 (from CACES). References such as Means and Dodge were also used for pricing. Army location adjustment factors published in AR 415-17[8] were applied to adjust material costs to the actual geographic location.

Frequencies

Three frequencies of occurrence are given for each task. The first is the earliest expected time period that the task would be performed. The second is the average time when the task would occur. The third is the latest expected time the task would be performed.

[8] AR 415-17, *Cost Estimating for Military Programming* (Headquarters, Department of the Army, February 15, 1980).

All task information was developed using published data when available. When published data was not available, the developers' experience was applied. All task data was reviewed and approved by craftsmen at the 10 test installations.

Component Summary

Manual application of the task data base is very labor-intensive and impractical. An annual resource summary has been produced containing total annual labor, material, and equipment resources for the first 25 years of component life. This data base can be applied to life-cycle costing studies more easily than the task data base. A typical component summary is shown in Table 2. A comprehensive description of the component summary development process and the complete data base have been published in the USACERL Special Report series titled "Building Component Maintenance and Repair Data Base."

Life-Cycle Costs

Maintenance costs are required to perform life-cycle cost (LCC) analyses in the design process. The present worth factors applied most often in Army LCC analyses are 7 and 10 percent. The component summary tables were adjusted by the 7 and 10 percent mid-year present worth factors to produce two sets of simpler tables. The Washington, DC labor and equipment rates were used to produce a total cost per unit measure for that area. Table 3 is a typical LCC analysis form. A comprehensive description of the LCC analysis development process and the data base have been published in the USACERL Special Report series titled "Building Maintenance and Repair Data for Life-Cycle Cost Analysis."

Current Use Summary by Annual Resources

The task data base was applied to each of the modeled facilities at the test installations to produce a resource requirement for facility ages 1 through 80 or 120. The annual resources for all modeled facilities with the same Army Facility Classes and Construction Category Codes (F4C) were averaged and normalized to form the average annual resource requirement by facility age for each F4C category. A typical set of data is shown in Table 4.

This data can be used given the following data elements: (1) geographic location adjustment factor, (2) current use F4C, (3) year built, (4) square feet of floor area, and (5) local labor and equipment cost per hour. A comprehensive description of the development process and data base is published in the USACERL Special Report titled "Maintenance Resources by Building Use for U.S. Army Installations."

Current Use Summary by Cost per Unit

Predicted costs to maintain each modeled facility were calculated using the task data base and actual installation cost figures. Costs were summarized into two groups: (1) replacement and high-cost tasks; and (2) all other nonreplacement and high-cost tasks, which will be called the annual recurring maintenance costs. These two groups of costs were averaged by individual current use code and then normalized by dividing the costs by the unit of measure. The unit costs for each installation were normalized to the Washington, DC area by applying the location adjustment factor. The DC unit costs for each installation were averaged to form an average unit cost at Washington, DC by facility age and F4C. The only data elements needed to use this data base are: (1) geographic location adjustment factor, (2) current use F4C, (3) year built, and (4) square feet.

Table 4

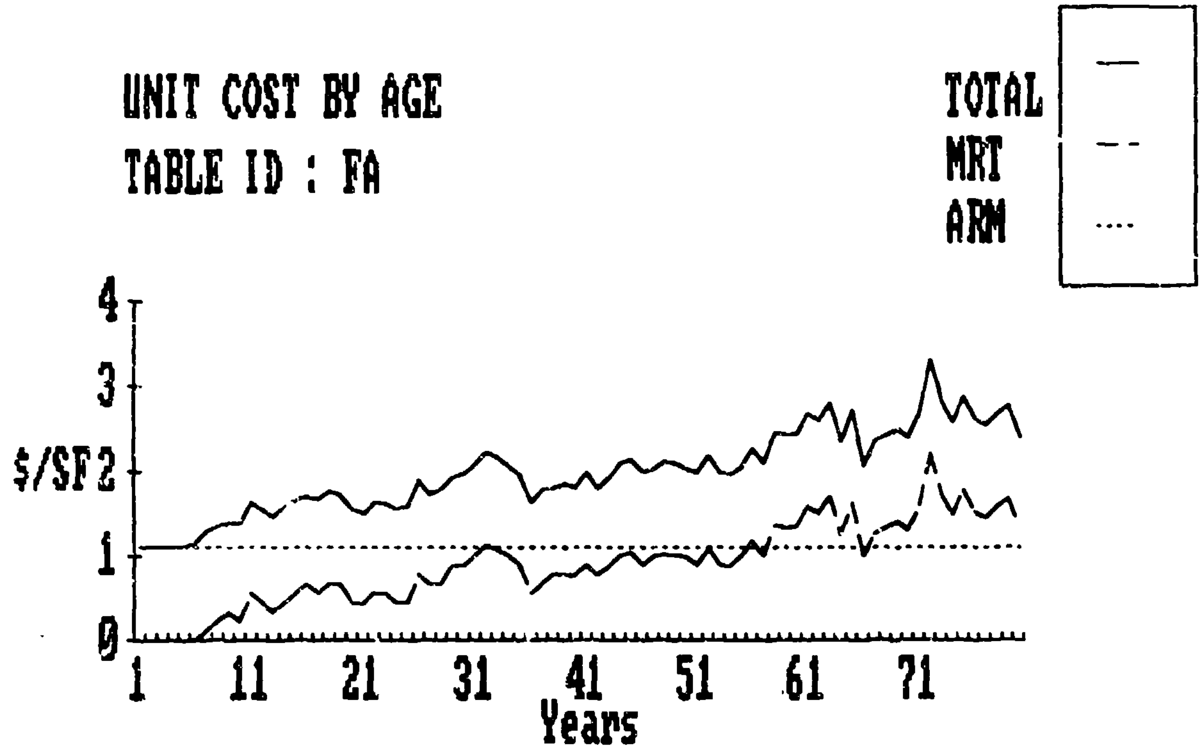
Typical Resource Summary Data

04-21-89   10:21:17   Installation : LEARNING THE MRPMS SYSTEM   Page 1
Unit Cost Factor Data File

Code ID FA
Unit Cost Special Condition Multiplier 1.00
Annual Recurring Maintenance Factor 1.10
MRF for Major Cost Tasks and Replacement Tasks

	Age									
Decade	1	2	3	4	5	6	7	8	9	10
0	.000	.000	.000	.000	.000	.050	.190	.240	.300	.280
1	.530	.440	.360	.470	.560	.600	.570	.660	.620	.450
2	.400	.530	.520	.450	.480	.790	.620	.690	.820	.870
3	.980	1.130	1.060	.960	.850	.530	.680	.700	.750	.710
4	.880	.700	.820	1.000	1.040	.890	.930	1.020	1.000	.930
5	.890	1.080	.880	.870	.950	1.170	1.000	1.360	1.330	1.350
6	1.580	1.510	1.700	1.250	1.620	.970	1.260	1.330	1.410	1.300
7	1.590	2.210	1.740	1.480	1.770	1.520	1.450	1.580	1.670	1.320

One example is shown in Figure 3. A comprehensive description of the development process and data base is published in the USACERL Special Report titled "Maintenance Resources by Building Use for U.S. Army Installations."



MRT = Major and Replacement Task Cost
ARM = Annual Recurring Maintenance Cost
TOTAL = Sum of MRT and ARM

Figure 3. Typical current use summary.

4 PREDICTION MODELS AVAILABLE

Five types of prediction models are available. Four models were computerized under this research program and one is for manual application or use within other computer systems. Each model is described below.

Average of Actual Expenditures

The Army maintains historic unit cost expenditure data by generalized facility use categories. For example, hospital M&R expenditures are recorded in dollars per square foot of floor area. The past 5 years' data has been adjusted for inflation to the current year as a base and then averaged. Army average data is published by current facility use for planning and programming applications. This data is available for every installation, MACOM, and the total Army, and was computerized under this research program for application at all management levels. Use of this model produces one average annual total cost figure.

The model uses two facility data items, both of which are currently available in IFS: (1) current facility use and (2) unit of measure. The current facility use is applied to identify the correct unit cost per unit of measure such as square feet of floor area. The unit cost is multiplied by the facility's unit of measure to obtain a total cost.

The model can be applied to both individual facility and organizational summary data. Summary data can be formed by combining all facilities of one type (hospitals) built in the same year (1962) at any organizational level such as HQDA, MACOM, or installation. The floor areas of all such facilities are added together to represent one facility group.

Resources by Facility Age

Three basic data items are available in IFS for every facility in the Army inventory: (1) the current use of the facility, (2) the year of construction, and (3) a unit of measure, such as floor area for buildings. This prediction model uses the three basic data items coupled with unit cost by age data indexed by facility current use. The unit cost by age data was developed from a detailed analysis of the tasks that should be performed to keep facilities at several test installations in a standard operating condition. The resource data includes unit costs, labor hours, equipment hours, and material costs in Washington, DC dollars. The four data items are stored by facility age. As an example, for hospitals, the unit cost, labor hours, equipment hours, and material cost for a hospital facility at 24, 44, and 65 years old is shown in Table 4.

The computer can calculate resource predictions in one of two ways:

1. The current age of the facility is obtained by subtracting the year constructed from the prediction year. This facility age, coupled with the current use, is applied to locate the correct unit cost by age. The unit cost is multiplied by the square footage to produce a total cost in DC dollars. This cost is adjusted to the local economy by multiplying it by the location factor.

2. The model uses an installation's labor and equipment rates expressed in dollars per work hour. The Army publishes a cost adjustment factor to transfer the Washington, DC material costs to the actual installation. The computer system transforms age resources to calendar year resources by subtracting the

calendar year from the construction year. The following resource information for each calendar year in the reporting period is calculated: (1) labor hours, (2) equipment hours, (3) labor costs, (4) material costs, (5) equipment costs, and (6) total costs.

Resource requirements are different for each year, depending on the actual work that should be performed. Yearly requirements may fluctuate greatly from year to year for an actual facility.

This model can be applied to both individual facility data and organizational summary data. Summary data can be formed by combining all facilities of one type (e.g., hospitals) built in the same year (e.g., 1962). The floor areas of all such facilities are added together to represent one facility group.

Facility Component Description

A facility can be described in more detail than the three basic data elements. Three examples will be given to demonstrate the possibilities.

1. Describe all components in a facility and calculate all tasks: the user describes a facility in any level of detail by listing construction components (e.g., maple plank floors, shingle roof). The more components defined, the more accurate the facility description. For every construction component there is a list of tasks that must be performed during its life. Each task has associated labor, material, equipment, frequency, and trade information. The computer calculates resources for every task, then sums all tasks into a component summary. Component summaries are combined into subsystem (floors) totals; subsystem totals into system (interior finishes) totals; and finally, system totals into total facility (building) resources.

2. Describe all components and calculate major cost tasks: each task is classified as either a major cost task or a minor cost task. Major cost tasks are defined as all replacement tasks and other tasks that cost more than half of the total replacement task cost. All minor tasks have been combined into one summary record. The computer calculates each individual major cost task and uses the summary record instead of the individual minor cost tasks.

3. Describe components in high-cost systems only, and use summary data for other low-cost systems: the program contains a system resource summary based on the detailed individual facility research described previously. All architectural finishes such as floor, ceiling, and wall components can be defined. Defaults to summary data for electrical, plumbing, and mechanical systems can be used. The computer system calculates the tasks for the components and uses a system summary record (labor, equipment, and material) for the electrical, plumbing, and mechanical systems.

This option allows a facility to be defined in any way and with any level of detail. Average data is used to cover systems not defined by components.

Facility Age

This model uses the facility component description to perform calculations by the facility age for any age from 1 year to a maximum of 120 years. This model is used to determine the Army average resources for use within the calendar year models described above. This model was used to produce the Army average unit costs and resources applied in the two methods described above and in the tables described below.

Life-Cycle Cost Models

This model is used during design to assist in the selection of least-cost components over the facility life.

One present worth table is published for each trade or discipline for both a 7 percent and 10 percent present worth factor. An example is shown in Table 3. The designer reviews this table before selecting components in a design.

Normally, the installations's actual labor, material, and equipment resource rates are multiplied by the resources in the table. For gross comparisons or when no installation labor/equipment cost rates are available, the application which is fastest and the least amount of work is for the designer to use the 25-year present worth unit cost for the Military District of Washington, DC. By quickly reviewing this column, the designer can make a fairly accurate selection.

These tables also provide resource information for input to other life-cycle costing computer programs that perform present worth factoring. An equivalent uniform resource requirement is given to cover all minor cost tasks. All major cost tasks are listed individually with the average frequency of occurrence. This data can be used in a computer program such as USACERL's Life-Cycle Cost in Design (LCCID) Program.

5 COMPUTER SYSTEM DEVELOPMENT

Large amounts of labor resources are required to use the data manually. Since labor resources within the Army are always decreasing, the need for automation was clear. Selection of the type of computer system to be used required careful consideration. Three computer systems were developed: (1) worldwide mainframe system, (2) an organizational system, and (3) an installation research system.

Worldwide Mainframe Computer System

HQUSACE has a mainframe system known as the Headquarters Integrated Facilities System (HQ-IFS). The average actual expenditure and yearly average prediction models were required to be implemented as a module of the existing HQ-IFS. This system uses the NOMAD II relational data base programming language and is available on a worldwide timesharing network.

This system has some disadvantages when used at a level other than HQ or MACOM. For example, communication costs between the user and the computer are expensive. Also, telephone lines within installations are not always modem and cannot always effectively support electronic communication. This system was therefore rejected for installations.

Organizational Summary System

This system operates under a DOS environment using a PC with at least a 10 MB internal disk. The system is designed to use summary data by facility use and age to calculate resources based on only three data items available in IFS: (1) current use, (2) construction date, and (3) floor area. The system can be used by HQDA, MACOM, and installations.

Installation Research System

PCs have several advantages over mainframe computers. For example, the PC owner has complete control over the computer. Also, there are no communication charges and the PC is always available.

The major challenge for this project was to develop a fast, interactive DOS environment PC system that could calculate maintenance requirements for a facility based on its actual components and their quantities. DOS was selected since more than 90 percent of all PCs, including the Zenith series, operate with this system. The basic machine selected for system development was an IBM-AT. Since the system required a large number of mathematical computations, a mathematics coprocessor chip was added to the basic configuration for a 30 percent increase in productivity. A 25 percent increase in speed was obtained by adding the maximum allowed random access memory (RAM) and performing all calculations in RAM. In addition, because disk access through DOS was slow, commercial software packages such as the Software Masters FLASH system were installed to allow DOS tables normally located on disk drives to be stored and accessed in RAM. This change increased speed by another 25 percent.

Programs were written using the Microsoft FORTRAN and CHART programs and the SoftCraft BTRIEVE record management system. Special programs were developed to allow optional initial data entry using LOTUS 1-2-3 and SYMPHONY. Total program space is approximately 12 MB.

Data storage was the next problem to overcome. Using the facility component description method model, each facility requires more than 120,000 bytes of disk storage. Most installations have between 4000 and 10,000 individual facilities.

The largest available disks were added to the system. Two to four 620 MB disk drives are currently installed.

Life-Cycle Cost System

A set of DBase III programs was developed to produce the present worth tables for use by designers in selecting the most economical component over the facility life. The system operates under a DOS environment on a PC. It can produce tables covering any time period for any discount factor.

6 FIELD TEST RESULTS

Over this 8-year R&D effort, several military and civilian organizations have tested the products as described in Chapters 1 and 2. The results are presented below.

Data Bases

Component Task

The task data base described in Chapter 3 has proven to be an invaluable product. Private firms, including MMM, Inc. and Marinni and Associates, have used the data to produce facility resource requirements. Several DA contractors have used the data base on projects such as the LRSS, RPLANS, and historical family housing studies. Forts Bragg and Leonard Wood have verified that this task data base produces accurate resource predictions for developing both short- and long-range plans. The data base covers all building construction components.

The Army will need to review and update this data base periodically to keep it current with changing technology, construction materials, and workmanship. The updates should be published for use by other organizations.

Life-Cycle Cost

This set of tables, described in Chapter 3, allows designers performing both new construction and alteration project designs to select the least costly component. Architectural/engineering firms can use this information as a reference in preparing LCC estimates.

The Army will also need to review and update the tables periodically to account for new technology and materials. Revised tables should be published for application throughout the Government and in the private sector. The American Society for Testing and Materials (ASTM) plans to publish this data as an ASTM standard.

Average Actual Expenditures

At present, this is the Army's best source for historical data such as average unit cost factors. However, managers at all test installations in the program stated that the data is incomplete for planning purposes, as some actual expense data may be missing from the reports. The data represents what was spent from one funding account and not what should have been spent to maintain the facility. Therefore, this data represents the lower range of forecasting requirements.

The Army should continue to update this information yearly. Methods to ensure completeness of actual expenditures reporting need to be developed. Procedures to account for resources that should have been expended but were not available should also be developed to provide an accurate planning tool for future requirements.

Models

Average of Actual Expenditures

All test installations in the program agreed that this model is not useful due to two shortcomings in the data currently available: (1) data reflects only funds actually expended, not funds that were or should have been programmed and (2) actual recorded expenditures may be incomplete or recorded against the wrong facility.

The installations stated that this model should be used with caution to estimate the lower bound on possible resource requirements. Comparison of installation data with MACOM- and Army-level averages showed large fluctuations.

Resources by Facility Age

This model seems to be ideal for macro applications in HQDA and the MACOMs. It allows the results of detailed modeling for a small set of select facilities to be applied to the complete Army inventory by using only limited available data. The model requires few labor resources to obtain a resource prediction. However, the predictions are not accurate at an individual facility level. Moderately accurate results could be obtained at the installation level.

Facility Component Description

The steering committee found that this set of models produces the most accurate resource predictions, but requires detailed knowledge of the facilities and manpower to keep the knowledge current. Installations will not readily apply these models for the following reasons:

1. A data base containing facility component data does not currently exist at the installation.

2. The cost of obtaining any portion of the data is high.

3. Manpower to operate and maintain such systems is not available within most installations.

4. Short- and long-range planning is not currently a function performed by installations.

An installation that desires to know more about its facilities can do so gradually by collecting the data in small increments as required to perform normal business activities. This method has been used extensively in research at all test installations. The steering committee has stated that the system should be maintained to evaluate maintenance costs for all new standard designs under construction by the Army.

<u>Select Component Identification</u>. Only high-cost systems with components such as roofs and exterior/interior finishes need to be recorded. Once initial data is input, changes are required only when the components are replaced. All other systems can use the Army average data. All of the test installations believe that this is the best approach to obtain a more accurate resource estimate at the installation level. It requires the minimal amount of installation resources of the models in this set.

<u>All Component Identification--High-Cost Task Calculation</u>. The test installations have stated that this model will be applied by only a few installations due to the cost of obtaining the initial data base.

<u>All Component Identification--All Task Calculation</u>. Once again, the test installations stated that this model will be applied by only a limited number of installations due to the high cost of the initial data base.

Facility Age

This model will be useful only to a limited number of research organizations that are exploring relationships between resources and facility age.

Life-Cycle Costs

This model will be used by the USACE and installation designers for new construction component selection. Designers can also use it to perform renovation/modification designs. Data will be updated by HQUSACE.

Computer Systems

Worldwide Mainframe Computer System

This computer system is used by the Real Property Management, Army Programming Branch, Office of the Assistant Chief of Engineers. The system is used to calculate resource requirements at the MACOM and Army levels for comparison data against the requests of each MACOM. The system should be maintained as a function within HQ-IFS.

Organizational Summary System

MACOMs use this system to calculate resource requirements when preparing their planning submissions. The system is available to installations. It needs to be maintained to support the users.

Installation Research System

This system is currently used by several installations, research organizations, and Army contractors. It needs to be maintained to support the large investments of labor and dollars expended by the installations to improve their management capabilities.

Planning Within the U.S. Government

During this project, both Congress and the Army began to place more emphasis on planning and programming. Congress' record on approving a budget before the end of the budget year is a clear indicator of the new emphasis on planning.

Use Within the Army

HQDA has decided to make the planning function an installation responsibility. However, implementation has been an extremely slow process interrupted by a major Army reorganization. At present, this function is still located at the DA and MACOM levels. Installation involvement is not foreseen in the near future. Installations will not need the planning tools developed under this research until they receive the planning functions from their MACOMs.

Use Outside the Army

Products of this research are being used by other Government agencies, including the Navy, Department of the Interior, and National Security Agency. The private sector is also using these products, including Pennsylvania State University, the University of Idaho, and ASTM.

7 CONCLUSIONS AND RECOMMENDATIONS

The products of this research are a comprehensive data base containing M&R cost data for Army facilities, prediction models for outyear maintenance requirements, and computer programs to facilitate manipulation of this data. Development of these products was coordinated with all affected Army offices at the Headquarters, MACOM, and installation levels. The data base and models were field tested at 10 installations in the United States and West Germany.

Field tests showed that the data base and prediction models increased the accuracy of life-cycle cost analyses. Disadvantages identified by the test installations were the high first cost of developing site-specific data bases to use with the installation computer programs, the continuing cost of keeping these data bases current, and the lack of manpower to perform this work.

This 8-year research project has provided HQDA, MACOMs, and installations with the tools needed to perform the planning and programming function. HQDA views installation involvement as a way to introduce more accuracy into programming decisions. At present, the planning and programming function remains primarily at the HQDA and MACOM levels.

The products developed in this study have extended the state of the art in facility maintenance planning and programming. The systems are being used by HQDA, MACOMs, and some installations. Technology transfer to the private sector looks promising, with these research products being used by several universities and professional societies such as ASTM.

It is recommended that the Army keep the data base and computer systems updated as new information and technology emerge.

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LIST OF ACRONYMS

ACE	Assistant Chief of Engineers
AMS	Army Management System
APC	Account Processing Code
AR	Army Regulation
ARR	Annual Requirements Report
ASTM	American Society for Testing and Materials
BLAST	Building Loads Analysis and System Thermodynamics
BMAR	Backlog of Maintenance and Repair
CA	Commercial Activities
CACES	Computer-Assisted Cost Estimating System
CONUS	Continental United States
DA	Department of the Army
DEH	Directorate of Engineering and Housing
DOD	Department of Defense
EA	Economic Analysis
EPS	Engineered Performance Standards
HQ-IFS	Headquarters - Integrated Facilities
HQDA	Headquarters Department of the Army
IFS	Integrated Facilities System
IJO	Individual Job Order
LCC	Life-Cycle Cost
LCCID	Life-Cycle Cost in Design
M&R	Maintenance and Repair
MACOM	Major Command
MCA	Military Construction, Army

MRPM	Maintenance Resource Prediction Model
OCE	Office of the Chief of Engineers
PAVER	Pavement Maintenance Management System
PC	Personal Computer
PM	Preventive Maintenance
R&D	Research and Development
RAM	Random Access Memory
RMF	Recurring Maintenance Factor
RPI	Real Property Inventory
RPLANS	Real Property Planning System
RPMS	Real Property Management System
SO	Service Order
STANFINS	Standard Army Financial System
TB	Technical Bulletin
URR	Unconstrained Requirements Report
USACE	U.S. Army Corps of Engineers
USACERL	U.S. Army Construction Engineering Research Laboratory
USAEHSC	U.S. Army Engineering and Housing Support Center

APPENDIX A:

METHODOLOGY AND PREDICTIVE MODELS TO FORECAST MAINTENANCE AND REPAIR REQUIREMENTS FOR ARMY REAL PROPERTY

The Problem

Army facilities are aging and major subsystems (components) are failing. New construction has added more facilities but replaced few, and the technological complexity of facilities has expanded because of new criteria. Resources for maintenance and repair have not kept pace with requirements, and deterioration of the physical plant is widespread. This is reflected in the backlog of maintenance and repair of active Army facilities which increased by $2 billion over 10 years before finally being contained in FY82; it has now begun to grow again.

The Army did not unconsciously allow facilities to erode unchecked. While there has been disruption in funding during program execution and a large dependency on migratory monies at year end, the basic trouble can be traced to ineffective resource planning. Repeatedly over the last 20 years, the conclusions and recommendations of RPMA studies and audit reports have expressed the need to improve methods for planning, programing, budgeting, and executing M&R activities (Table A1). These recommendations have not been ignored, but have not been fully accomplished largely because of:

- Difficulty in developing relationships between facilities characteristics and resource requirements.
- Lack of an accepted quantitative method of evaluating and measuring maintenance needs.
- Lack of a consistent long-range program which measures results achieved vs. resources allocated.
- Inconsistent methods of calculating funding requirements and lack of uniformity in applying terms and standards.
- Lack of life-cycle costing techniques for individual facility categories.
- Focus on budget formulation and near-term work management.
- Failure to implement and use resource management plans and information available in IFS.

A way to resolve these factors is to develop a quantitative method and predictive model that uniformly address the needs of the Army's physical plant in a programmatic manner. This appendix presents a study concept that will lead to adoption of an analytical method of resource planning that is: (1) oriented to the unique features of facilities management; (2) susceptible to refinement without fundamental changes in concept; (3) uniformly adaptable at installations worldwide; and (4) a means of relating M&R construction to create an integrated real property plan.

Table A1

Synopsis of RPMA Studies, Audit Reports, and RPMS Conferences

1. Congress Cannot Rely on the Military Services Reported Real Property Maintenance and Repair Backlog Data	GAO Rept 81-19 2 February 1981 OSD Case 5555
2. Management of Real Property Maintenance and Repair	AAA Rept HQ 82-207 25 January 1982
3. DOD's Real Property Maintenance and Repair Backlog	GAO Rept 79-314 31 August 1979 OSD Case 5228
4. Department of the Army Study Group on Real Property Management Activities	DA RPMA Study March 1978
5. Joint Service RPMA Programming and Budget Working Group	Jortberg Study Circa 1975
6. Lincoln Study (1968)	OCE RPMA Study December 1968
7. Evaluation of RPMA in DOD	Raymond Report May 1963
8. DOD Real Property Maintenance Management Conference I	RPMM Conference I 23-25 September 1964 (Prepared March 1981)
9. DOD Real Property Maintenance Management Conference II	RPMM Conference II 16-18 December 1969 (Prepared March 1981)
10. DOD Real Property Maintenance Management Conference III	RPMM Conference III 2-4 November 1971 (Prepared March 1981)
11. DOD Real Property Maintenance Management Conference IV	RPMM Conference IV 29-31 January 1974 (Prepared March 1981)

Alternative Approaches

Methods for defining maintenance needs and programs are traditionally one of the three following types:

Straight Line or Historical Funding - The previous year's budget base is incremented by a certain percentage annually to compensate for identified changes such as inflation and personnel trends.

Identification of Needs Based on Physical Survey - A comprehensive facilities inspection is conducted to identify and quantify all current maintenance deficiencies.

Formula Funding - Annual maintenance requirements are expressed in terms of cost per square foot, staffing criteria, population, or a certain percentage of physical plant value.

Each of these methods has one or more major deficiencies. Historical funding does not relate funding levels to identified needs. The base being incremented cannot be analyzed or validated. Activities which are subject to multivariable influences year to year are not well represented. Frequently, this data is used for lack of anything better when the analyst is removed from the situation. Since it projects the future according to the past, basic assumptions are that requirements will occur at a constant rate, and that the past itself is reliable.

Physical surveys provide an accurate assessment of current conditions and immediate needs, but are very labor-intensive. In addition, they have limited utility for identifying long-term requirements.

Formula funding is quantitatively based and is a systematic way to use simple ratios to project future needs. When units are comparable, such formulas are easy to apply and can offer a basis for agreement between requestor and provider. However, this method is best suited to budget rather than program development, and is a macro method that cannot address the needs at a specific physical plant. The validity of one uniform set of ratios for all activities is questionable in view of the variety in age of facilities, missions supported, construction materials and methods, climate, and other factors. (Recurring maintenance factors have been calculated for facility accounts and are published in AR 420-16.)

Both historical and formula funding depend on an underlying logic that reduces all differences to a common denominator. When used blindly, they tend to force uniformity in costs, even when conformity is neither realistic nor representative of real needs. Also, budget formulas based largely on historical expenditure patterns will tend to perpetuate whatever inequities existed. Because of the identifiable life cycle of both facilities and their installed subsystems, the formula approach seems inappropriate. These cycles are critical in determining the necessary, and varying, funding levels for future years.

Two methods which are less traditional but frequently advocated as plausible approaches to sound facility resource planning are: (1) life-cycle cost for various categories and components of facilities and (2) maintenance management systems that apply the elements of identification, determination of M&R needs, economic analysis, and prioritization to specific facility classes or subsystems.

This study will evaluate all approaches to determine which will work best now based on existing data bases and systems, and future directions that will allow the methodology to evolve according to the best approach to serve the planning and programming process at all levels.

The Conceptual Framework

To keep the study aligned with its primary purpose, a framework has been established within which basic data sources. terminology, records, and reports will be critically examined to determine their contribution to, and effectiveness in supporting the RPMA planning, programming, and budgeting process.

Fundamental to this conceptual framework is the premise that there are predictable cycles for facility repair and replacement (i.e., the components or subsystems of a facility such as heating, cooling, flooring, electrical, roofing, and structure have identifiable life expectancies and will require replacement after predictable periods). These cycles will continue to repeat themselves, and during the useful life of the facility there is a maintenance standard that must be maintained to achieve satisfactory service. The recurring maintenance that must be performed as well as the magnitude of replacement (major repair) that will occur at a specific time in the future are both important and can be identified separately. The combination of routine maintenance and replacement costs as specified frequencies will approximate the annual reinvestment necessary to maintain and repair the physical plant.

The framework to be followed has already been established and the basic building blocks are in place. The Army system provides for identification of facility types by construction categories and subsystems which are divided into components (Table A2). It is envisioned that the study will produce a predictive resource model by proceeding along the following path:

- Identify the features that have an impact on facility and system wearout.
- Identify underlying assumptions.
- Further define and quantify the identified features (variables).
- Model the physical plant and simulate future renewal/replacement requirements over time.
- Develop data to serve as input to a mathematical model.
- Validate results.
- Perform a sensitivity analysis.
- Use the results to estimate outyear M&R resource requirements.

The features and underlying assumptions can be described as:

1. Facility Type. The type of subsystems and associated costs vary with facility type.

2. Facility Subsystems. The quantity and type of installed subsystems (e.g., heating, plumbing) within a facility will determine future requirements.

3. Subsystem Life Cycle. The predictable life of components will determine the time at which future requirements will occur, and the associated maintenance can be tailored to the life-cycle pattern. The predictable life cycle may have an interdependency with that of other components.

4. Subsystem Cost. The unit replacement cost can be established based on technology and construction indices and can be uniformly applied to determine the cost of future requirements.

Table A2

Army Facility Types and Subsystems

1. DOD Facility Classes and Construction Categories	DOD Instruction 4165 24 October 1978 CH-1
2. Component Condition Criteria	Extract from IFS User Manual, Vol IV 1 September 1979

5. Date Facility was Constructed. The future point in time at which requirements will occur can be traced from the date that the facility was built and relative age (when major repairs were performed) of components.

It is considered possible to adhere to this framework because extensive research has been conducted and reports prepared on life-cycle costs and existing data bases (Table A3). This study is intended to act as a catalyst to examine this body of information and resolve the different issues raised so that the project can proceed with one unified, practical procedure.

The Study

I. Purpose. To design a methodology that includes predictive models for accurately forecasting future expenditures necessary to operate, maintain and repair, and renew the Army's physical plant.

II. Objectives.

1. Clarify terminology and express terms (i.e., annual recurring requirements, maintenance standards, manageable level of backlogs, replacement cost, economic life, age of a facility and deficiency dollars) in measurable forms that can be applied uniformly in the calculation of resource requirements.

2. Evaluate existing and proposed data bases to determine what and how data elements contribute to resource planning and related maintenance management decisions.

3. Determine how the current process can be improved; refine existing formulas as practical based on available data; design "best method and models" to accurately predict M&R requirements and test for feasibility.

4. Establish the criteria for estimating M&R costs associated with new construction. Identify O&M targets by facility subsystem for future MCA design criteria.

5. Ensure that methodology allows for expressing multiyear facility M&R strategies, permits results to be compared to the program, and analysis to be made of comparable facilities at different installations and between different MACOMs.

Table A3

Data Bases Other Than IFS

1. Life-Cycle Cost Data Base Volume 1, Design	USACERL TR P-139, A126644 January 1983
2. Overview of the "PAVER" Pavement Maintenance Management System	USACERL Tech. Manuscript M-310, A116311, March 1982

6. Ensure that models represent different types and uses of facilities and can be used by facilities planners/programmers to estimate and integrate different funding sources.

7. Design meaningful exhibits and reports to convey resource planning information among various management levels from installation to DA.

8. Revise publications (ARs, DA Pams) and issue uniform guidelines to implement process and steer system development.

9. Prepare a training course to educate users.

10. Share the results obtained with other DOD elements.

III. Scope

1. The Real Property Inventory (RPI) is the basic source of information for reports of status, cost, capacity, condition, use, maintenance, and management of real property overall and for individual installations. This information resides in the IFS Assets data base. Since it supplies data needed to analyze features of the existing plant, the RPI will be thoroughly reviewed and evaluated. In conducting this review, other data bases, existing or proposed, which are designed to support special areas of facilities management will be examined. Particular attention will be given to the data base required for the Pavement Maintenance Management System (PAVER) and the data base recommended for life-cycle costing.

2. The study will focus on creating a predictive model(s) that can be used to accurately portray requirements by installation, and that allows for successive aggregation at MACOMs and DA. It is envisioned that, while accomplishing this goal, the research will also address some broader issues of integration between construction and M&R. The methodology must be consistent with and supportive of the concept of a fully integrated real property plan.

3. Methods and terms used by other Government agencies and selected private corporations to formulate resource plans will be surveyed. Studies conducted by other services will be considered along with Army studies to advance the survey and ensure that this study does not duplicate areas of research where previous work will suffice.

4. The IFS and functional descriptions for the IFS redesign effort will be scrutinized to identify data elements and outputs directly related to characteristics of the predictive model. Data collection procedures must be fully researched when developing predictive models and methodology.

5. Policy implications must be evident in the study and the scope of research must include the applicable DOD directives and instructions (Table A4). These should not be considered restrictive to the design of predictive models, but methodology which is a departure from current doctrine will be documented; recommendations to improve the process will be submitted.

6. Issues that may impact on resource requirements will be considered in the study. These are: commercial activities vs. in-house workforce; economies of scale based on realignment of activities; consolidation among nearby installations; and base closures based on disproportionate spending. The models must allow meaningful analysis of these issues.

IV. Approach

1. Participation by DA, MACOMs, and installations will be maintained during all stages of the study.

2. Study will form a task force representing the best mixture of Government employees and contract consultants.

3. Decision-makers will evaluate results at key steps to ensure that the approach is practical, adequate, and suitable for adoption.

4. The study will attempt to develop algorithms to estimate cost (using existing data base and regression/correlation analysis) for near-term application (Phase I); then will proceed following the conceptual framework to determine the data bases and systems best suited to effective resource planning (Phase II). Feasibility of alternatives will be tested at selected sites. The approach should allow for logical progression from the basic analysis of variables influencing past expenditures (for a given piece of real property, these variables include age, size, condition, type of construction, mission, intensity of use, location, etc., and those related to economics, contracting practice, and management policy) to the final integration of ideas and techniques developed thus far. A total systems approach to resource planning for facilities is the ultimate aim.

Table A4

DOD Directives and Instructions

1.	Procurement of Services for the Maintenance, Repair and Construction of Real Property	DOD Instruction 1135.2 14 January 1975 CH 1-3
2.	Technical Publications Concerning Real Property Activities	DOD Instruction 4165.11 10 July 1973 CH 1-2
3.	Inventory of Military Real Property	DOD Instruction 4165.14 21 December 1966
4.	DOD Real Property Maintenance Activities Program	DOD Directive 4165.2 21 February 1976 CH 1-3
5.	Utilization and Retention of Real Property	DOD Instruction 4165.20 29 August 1958
6.	Program Control System for Real Property Maintenance Activities	DOD Instruction 4165.58 8 August 1973
7.	Program for Improvements in Financial Management in the Area of Appropriations for Acquisition and Construction of Military Real Property	DOD Directive 7040.2 18 January 1961

APPENDIX B:

ALTERNATIVE PREDICTION MODELS

1 Introduction

1.1 Objective

The ultimate aim is to apply a total systems approach to resource planning for facilities.

The objective of this appendix is to list all models that are either available now or will be in the future from the simplest to the most complex, with no comparison.

The prime objective statements for a model are as follows:

a. The model must be based on the actual facilities at each installation.

b. The model must be able to address the effect of not funding programmed work on future program requirements.

c. The model must be implementable as quickly as possible. It is envisioned that the steering committee will compare and evaluate all models and then select a model that is:

- Oriented to the unique features of facilities management.
- Susceptible to refinement without fundamental changes in concept.
- Uniformly adaptable at installations worldwide.
- Able to serve the planning and programming process at all levels.
- Able to accurately forecast future resource requirements necessary to maintain and repair the Army's physical plant.

1.2 Accuracy

The accuracy of any model will depend on several factors. A few of the major factors that must be considered during the development of a model would be:

a. Level of effort expended for maintaining an accurate data base.

b. Level of actual facility inspection, varying from none to complete inspection.

c. Sampling techniques that might be applied to select facilities if inspections are required.

d. Relationships between the components measured and the predicted resources.

e. Research expended to document the effect of different factors on the accuracy of the model (e.g., what is the actual difference in accuracy when using total square feet of floor area to predict floor M&R resource requirements vs. using the actual square footage of each type of floor within the facility).

1.3 Validation

If the model is to be validated through the collection of historical data within IFS, the IFS data must be able to be combined into the factors used by the model. The redesign IFS will have four new component digits to identify components. There are several problems with such validation procedures:

a. If funding provided is always below the required funding level, the historical data could possibly be misleading as to actual needs because work would not be performed when needed.

b. If USACE's recording system cannot be related to the model, it would be very difficult to validate the model. If the choice of using the new component fields is left to the individual installations, the fields may never be used. Installations may decide that the new fields provide no useful information to the installation and/or the installations would not care to spend the extra manpower to record at the detail level.

c. If managers schedule work in order to reach specific installation goals the data would not be as useful.

1.4 Factors

The model to be developed should consider the effects of the following factors:

a. Occupants.

b. Weather.

c. Logistics (movement from base to job site).

d. Indirect resource (managers, supervisors, support personnel).

e. Under-/over-funding.

f. Mission.

1.5 Historical Data Available

The four basic sources of historical data within the USACE are:

a. IFS.

b. STANFINS (Standard Army Financial System).

c. Annual Summary of Operations/Technical Data Reports.

d. Paper Records.

Each source is described below.

<u>IFS</u>. During each fiscal year, the installation maintains two files that together comprise the most detailed data available. The first file, known as A35AKB, contains all records entered into IFS during the past 30 days. After the 30-day period, the records are moved to the A70 History file. At the close

of a fiscal year, the A70 file contains all records issued during that year. Unfortunately, most installations have not kept the A70 files for future reference. The installations have stated that a letter was received during the first quarter of FY84 requesting that the A70 files be saved for possible future application. Most installations have saved the FY83 A70 file as requested. The best cost information that is available through the IFS system is as follows:

- Actual records for in-house work on each facility during FY83.
- The R&D cost files that contain costs per component per facility for the current fiscal year, the previous fiscal year, and the total since IFS was implemented.

STANFINS. The Standard Army Financial System, known as STANFINS, contains all cost data for each installation. The most detailed level of information available is the Account Processing Code (APC) which is a four-digit code applied to facility types only. STANFINs records have been available at most installations since 1979 in an annual summary format. STANFINS data are not coded by individual facility or individual component. The system is currently being redesigned to contain fewer APC codes, thus reducing the level of detail within the system.

Annual Summary of Operations/Technical Data Reports. Installations have been required to produce annual summary information by the Army Management Structure (AMS) Codes--the Technical Data Report. The unit of measure and base unit quantity information are obtained from several installation sources. The total costs figure is basically obtained from STANFINS. The lowest level of information available is by AMS code. Information about individual facilities or components is not available.

Paper Records. Service order (SO) and individual job order (IJO) documents are normally retained for 1 or 2 years. Other paper records are usually held for less than 1 year. Some records for contractual work may be kept for a longer period.

1.6 Format

The basic alternative prediction models addressed include:

a. Continuation of the current method.

b. Historical funding.

c. Installation 5-year plan through application of shop knowledge.

d. Application of existing IFS data.

e. Application of expanded IFS-R data.

f. Fixed percentage of the current replacement cost.

Each alternative prediction model will be summarized as follows:

- General description
- Model Development

- Advantages
- Disadvantages.

1.7 Model Selection

More than one model may be used in forecasting total M&R requirements. It is possible that completely different models would be selected for different groups of AMS codes. Totally unique facilities, such as ranges, could apply a shop knowledge driven 5-year plan. Similar facilities, such as buildings, could apply facility component life-cycle data. Highly equipment oriented facilities such as water and sewage treatment plants could apply resource requirement models at the level of an individual piece of equipment.

2 Model 1: Continuation of the Current Method

2.1 General Description

The current model requires that each continental United States (CONUS) installation develop an annual Unconstrained Requirements Report (URR) and a list of Backlog of Maintenance and Repair (BMAR) activities. BMAR activities are URR activities that were scheduled in previous years but not funded. In Europe, the Major or Subordinate Command develops the URR documents for the installations. OCE develops a 5-year funding requirement report based on the MACOM's annual URR and BMAR. The model assumes that the annual M&R requirements are constant for each installation and these costs increase only with inflation. The sum of the following three items comprise the total resources for the current model:

a. Inflation-adjusted URR.

b. BMAR to be completed during the year.

c. Further deterioration of facilities caused by unfunded BMAR. The URR is adjusted by inflation factors to produce cost figures for 5 outyears. It is assumed that a percentage of the BMAR will be funded each year. This BMAR percentage is adjusted for inflation. It is also assumed that the unfunded BMAR facilities will continue to deteriorate at a fixed percentage per year until the BMAR has been completed. Unfunded BMAR is also adjusted for inflation.

2.2 Model Development

No development is required as the model is currently in place and working. This is a manual process in which hard copy tables are generated from summaries provided to Office of the Chief of Engineers (OCE) by the MACOMs.

2.3 Advantages

a. The system is already developed.

b. The system requires minimal involvement by the installation.

c. The system requires no additional installation manpower resources to maintain.

d. This system requires very little data.

2.4 Disadvantages

a. This model is not based on the actual condition of the facilities at an installation.

b. This model cannot be applied to identify the actual M&R needs of the facility, installations, subordinate commands, or MACOMs.

c. It is difficult to support or document this model to higher authorities.

d. What-if questions cannot be answered with this type of model.

e. This model is not based on the actual management procedures at an installation.

f. This model does not involve the creation of standard M&R procedures for use throughout USACE.

g. This model could result in continually underfunding M&R requirements, leading to a general decline in facility maintenance.

3 Model 2: Historical Funding

3.1 General Description

This model requires little effort by the Directorate of Engineering and Housing (DEH). Recurring maintenance factors (RMFs) are published in AR 420-16, *Facilities Engineering Reports*. These factors are 5-year average costs per unit measure per facility category code. These costs are based on 5 years of historical data, adjusted for inflation.

3.2 Model Development

No additional work is needed as the data is in the Red Book and the RMFs are updated by HQUSACE.

3.3 Advantages

a. The Annual Summary of Operations data are normally prepared yearly under the current system.

b. Requires no additional installation participation.

c. Results are easy to calculate and apply.

3.4 Disadvantages

a. This model does not relate funding levels to identified needs.

b. The model assumes that the funding for previous years was adequate.

c. The incremented previous years' data cannot be analyzed or validated.

d. Activities subject to multivariable influences year to year are not well represented.

e. The model assumes that requirements will occur at the same constant rate as in the past.

f. This model forces uniformity in costs even when this is not realistic or representative of real needs.

g. The model tends to perpetuate whatever inequities existed in the past.

4 Model 3: Installation 5-Year Plan Through Application of Shop Knowledge

4.1 General Description

This model would require the DEH to manually prepare a 5-year M&R plan by individual facility or facility group. This model would be a manual spreadsheet form approach to the development of an M&R prediction plan. A standard spreadsheet form would be developed for each major facility type. Each installation would be required to submit summary forms by facility category codes to the next higher command. Each installation would be free to develop the total annual M&R requirements as it wishes. Some facilities could be handled on an individual basis. Other facilities could be combined and handled as one logical group. The shop knowledge envisioned is the current visual inspection being performed by the tradesmen as they perform their daily preventive maintenance (PM), SO, and IJO tasks. No additional inspection would be required.

4.2 Model Development

This model would require the design of standard forms to address all facility types. A set of written instructions would be prepared to document the process. The standard forms could be completed using PC spreadsheet systems and forwarded using PC diskettes if installations and MACOMs desired to support this approach.

4.3 Advantages

a. This model provides a standard methodology for recording M&R requirements by individual facility or groups of facilities for all installations.

b. The model does not explicitly require the maintenance of a computerized data base but could be easily adapted for automation.

c. Each installation could calculate required resources based on its individual method for performing the work.

d. The model does not require establishment of M&R standards for any component as each installation applies its own standards.

e. Each installation could develop its own method for determining the data placed on the spreadsheet. Some installations might establish a very detailed life-cycle M&R system on PCs, whereas others might conduct coordination conferences to develop the data.

f. This model is based on the predicted M&R requirements for each facility as calculated by each installation.

g. It is easy to document the model for review by higher authorities.

h. The model creates useful information for installation management.

4.4 Disadvantages

a. This model requires that each installation become involved in developing the 5-year plan.

b. This model requires manpower to perform a new function at the DEH. Since no additional manpower would be provided and the DEH is already understaffed, if the benefit of this 5-year plan to the installations is considered marginal, very little manpower might be available to perform the task. The intended accuracy may also suffer.

c. There would be no uniformity across installations in work standards/methods.

d. It would be time-consuming and labor-intensive to answer what-if questions, but it is possible.

5 Model 4: Application of Existing IFS Data

5.1 General Description

This model uses only facility information obtained from the existing IFS. The installation can currently enter a limited amount of component information into IFS: at most, one construction type per component, one measurement quantity per component, and one date of the last component replacement. Computer programs would be added to HQ-IFS to calculate the M&R dollar resources based on the current data fields within IFS. This model would not require expansion of the current IFS capabilities. Computer programs would be maintained by USAEHSC and executed only by OCE. There would be no additional installation support requirement beyond the current need to keep the IFS data up to date.

Life-cycle costing by basic IFS components and/or meaningful Recurring Maintenance Factors could be applied to a few specific IFS components. The life-cycle cost method outlined below is presented as the best way to obtain detailed M&R data. For a building component:

a. A schedule of PM is determined using the manufacturer's recommendations, the contractor's experience, and other sources.

b. Each PM job is divided into tasks, and the manpower requirements for each task are determined using EPS or other DA technical documents.

c. The expected failure rate of the component is used to determine frequency of repairs.

d. Each repair job is tasked as in No. 2 above.

e. Material requirements are calculated for each PM or repair job.

f. Yearly total manpower and material requirements are calculated.

5.2 Model Development

Since the best currently available IFS information field to relate electrical and mechanical systems would probably be square footage and date of installation, research would be needed to relate such footage with M&R requirements. Likewise, research would be required to develop relationships for all other IFS component information fields. This would be a very difficult task in areas such as the IFS component named "structures." Algorithms would be developed for these relationships and HQ-IFS would be modified to include them.

All installation IFS component data bases would have to be updated and/or verified to reflect the actual facilities, including accurate contract data, construction materials, and replacement dates. A workable system for keeping the IFS data current would have to be designed and implemented since no current method is being applied successfully by the installations.

5.3 Advantages

a. No involvement is required of the installation to execute the model.

b. The model uses current fields within the IFS data base.

c. No additional computer hardware equipment is required.

d. The model does not require the establishment of maintenance standards for installations.

5.4 Disadvantages

a. IFS component construction type and replacement date data fields are not currently updated by installations. This data is not being used by the installation or OCE at present. There is limited accurate information within the IFS data base to be applied within the model.

b. Currently little information is kept in IFS about the electrical, plumbing, and HVAC systems. Information about interior wall construction, doors, and windows also is limited. The accuracy of predictions based on such limited facility information might be questioned. Information about nonbuilding-type facilities are even more general.

c. The model requires more installation spending to develop accurate construction material and replacement date data.

d. It would be difficult to evaluate the accuracy of the model due to the limited number of parameters applied.

e. It would be difficult to answer what-if questions due to the limited number of parameters applied.

f. This model does not produce a set of maintenance standards for application by installations.

g. It requires the development of new computer programs.

6 Model 5: Application of Expanded IFS-R Data

6.1 General Description

This model would use only facility information that would be obtained through a modified IFS-R system. This model would contain standard spreadsheet reporting formats to be applied by all installations. Installations would have the option of preparing spreadsheets manually or through application of an expanded IFS reporting system.

Manual Operation. The manual system could be used by installations that do not wish to maintain the optional expanded IFS-R data. A report containing life-cycle resources for each facility component would be provided. Each installation would review this data and make adjustments such that the data would conform to the installation's actual operating procedures. The installation would prepare handwritten spreadsheets for both individual and/or groups of facilities as required. Data reported would be based on the adjusted report data and knowledge of the actual facility conditions.

IFS Computer-Assisted Operation. Life-cycle resource data would reside within the installation IFS-R. Each installation would review this data and make adjustments to conform to the installation's actual maintenance procedures. The installation would enter the actual facility components and the number of identical facilities within the group. The installation IFS-R (or the HQ-IFS) computer would perform all calculations, reports, and provide a data base that could be queried interactively.

Possible Design Features.

1. First- and second-line DEH supervisors could interactively query the model to obtain M&R information.

2. The lowest level within the model would be the detailed facility component. DEH managers would establish the exact level of detail required for each facility.

3. The model would support the actual management system being used by each individual installation.

4. The model would group facility components into facility systems, systems into a total facility, and facilities into facility category codes.

5. MACOMs could review and revise cost figures submitted from lower levels and pass final approved command reports to the next higher level.

6. Funds could be allocated to subordinate levels.

7. Limited "what-if" activities related to a 1-year deferral of a component M&R activity could be performed.

8. A priority activity list based on reprogramming impact could be produced.

9. The model would allow installations to change estimated activity performance dates to conform with actual facility conditions.

10. The model would produce required activities and quantities for next year's Commercial Activities (CA) contracts.

6.2 Model Development

A report containing the DEH-defined and -approved level of detail necessary to accurately predict M&R resources will be provided through the steering committee to USAEHSC for possible inclusion in the current IFS redesign program.

As an expedient, interim, and temporary test solution until the release of IFS-R with the modifications, USACERL will develop required computer programs for PC applications. One PC would be used to test the model's effectiveness. The USACERL research team would provide the PC as part of the test equipment. The 10 installations would perform all calculations while this unit is onsite. Life-cycle resource requirements will be developed by USACERL for each detailed component defined by the DEH. Each component would have a minimum of two cycles: (1) M&R with no replacement and (2) M&R with normal replacement. What-if questions could be answered by comparing the two cycles.

6.3 Advantages

a. This model would provide the first draft of an engineering estimate of required resources for outyears which could be validated by a fast inspection program.

b. The model would provide a management tool to the installation.

c. The model would prov[illegible] a guide for stock ordering so that materials are always available before the expected need actually occ[illegible].

d. The model would provide an engineering-based requirement for in-house labor force request justification.

e. The level of detail would provide amounts for inclusion in the installation's CA documents.

f. The first draft of the URR would be produced.

g. The model would produce the first draft of the Annual Requirements Report (ARR).

h. The installation could select the level of effort to be used in implementing this model (manual vs. automated).

i. The model would be easy to document.

j. Each installation could calculate resources based on its individual methods for performing work.

k. The model could answer limited what-if questions.

l. This detailed model would contain M&R standards for uniform application throughout USACE.

6.4 Disadvantages

a. An accurate data base with more detail than any existing computer data base must be constructed and maintained. This would require manpower and dollars.

b. Some new installation management procedures would be required to ensure that accurate data is entered by technically competent personnel.

c PCs might be required at some installations to support this model until the prediction system is available through IFS-R and HQ-IFS.

d. This model requires that the installations assume an active role in predicting M&R resources.

e. The M&R teams would have to record activity numbers on the Labor and Equipment (L&E) cards for recordkeeping.

f. The model requires the establishment of general M&R standards that are modifiable by the installation.

g. The model requires a modification to IFS-R and HQ-IFS.

7 Model 6: Fixed Percentage of the Current Replacement Cost

7.1 General Description

This model uses the current facility replacement cost and a percentage multiplier to predict M&R requirements. The model would provide a constant percentage of the facility replacement cost each year for M&R.

7.2 Model Development

The actual life-cycle costs curve for a facility must be known before this information can be averaged and divided by the original construction cost to provide a percentage of the replacement value.

7.3 Advantages

a. This would be a very simple conceptual model.

b. It requires no additional work by installation personnel.

7.4 Disadvantages

a. An individual facility does not require a constant dollar expenditure per year. Therefore, the accuracy for a given year of this approach is questionable. Zero-based budgeting does not allow the building of escrow accounts.

b. Application of the original construction cost indexed into the future as a replacement cost does not produce an accurate replacement figure. When replacements are performed, the new building must apply the current design criteria, not the old criteria. The original costs to construct many facilities are unknown.

c. This type of approach does not consider the actual condition of the current facility or the effect of the occupant on it.

d. What-if questions cannot be answered with such a simplistic model.

e. Previous research by Stanford University has shown that such an approach cannot accurately supply needed resources in a timely fashion.

f. No actual maintenance standards are established by this type of model.

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